

# **NASA's Heliophysics Theory Program – Accomplishments in the Last Cycle.**

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# ABSTRACT

**NASA's Heliophysics Theory Program (HTP) is now into a new triennial cycle of funded research, with new research awards beginning in 2008. The theory program was established by the (former) Solar Terrestrial Division in 1980 to redress a weakness of support in the theory area. It has been a successful, evolving scientific program with long-term funding of relatively large "critical mass groups" pursuing theory and modeling on a scale larger than that available within the limits of traditional NASA Supporting Research and Technology (SR&T) awards. The results of the last 3 year funding cycle, just ended, contributed to ever more cutting edge theoretical understanding of all parts of the Sun-Earth Connection chain. Advances ranged from the core of the Sun out into the corona, through the solar wind into the Earth's magnetosphere and down to the ionosphere and lower atmosphere, also contributing to understanding the environments of other solar system bodies. The HTP contributions were not isolated findings but continued to contribute to the planning and implementation of NASA spacecraft missions and to the development of the predictive computer models that have become the workhorses for analyzing satellite and ground-based measurements.**

# HISTORY

- λ Established to redress perceived weakness in the theory area.
- λ (Former) Solar Terrestrial Division initiated it in 1980 as the Solar Terrestrial Theory Program (STTP) following a peer group study, *“The theoretical component of the space-plasma-physics effort needs to be strengthened by increased support and, most particularly, by encouraging theory to play a crucial role in the planned development of the field”* - NAS/NRC Space Science Board (1978).
- λ 2001 R&A Senior Review gave a positive evaluation of SECTP accomplishments but queried its relationship to LWS theory/modeling and recommended more participation in mission development. This has taken place.
- λ Most recent cycle of 3-year SECTP research awards started this year.

# GOALS

- Purview encompasses solar physics, heliospheric physics, magnetospheric physics and ionospheric, thermospheric, and mesospheric physics.
- Longer term funding of relatively large “critical mass”, synergistically interacting groups of investigators to attack problems of fundamental importance within, or transcending, the boundaries of the different disciplines within the Sun-Earth Connection science theme.
- Pursue theory and modeling on a scale not readily supportable within confines of traditional NASA Science and Technology (SR&T) awards.
- Support NASA missions and E/PO programs.
- Encourage the exploration and development of new areas in the Sun-Earth Connection, especially interdisciplinary ones and perhaps objectives for future space missions.

# HISTORICAL ACCOMPLISHMENTS

- Outstanding example of benefits accrued from stable support.
  - Total of 40 groups have participated for an average tenure of ~ 9 Years.
  - HEP (formerly SECTP) scientists have been PI's, Co-I's on spacecraft missions, organizers of topical conferences, participants in advisory and study groups at all levels.
  - Yielded models and research advances that would be nowhere near their current state of development without SECTP support. (e.g., IDEA, TDIM, TIME-GCM, AIME, RCM, Sun/Magnetosphere MHD Codes...). These models are now integral parts of all mission planning and spacecraft/ground based instrument data analysis and Space Weather prediction activities.
  - Last 3 year cycle of support (2005-2008) contributed to more than 233 publications. Thousands of publications over lifetime of program.

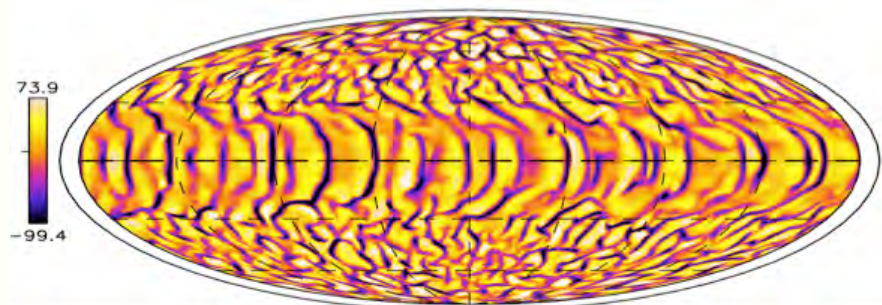
# LAST 3-YEAR CYCLE ACTIVITIES

- Nine investigations covered the Sun's interior, its surface, interplanetary space, the Earth's magnetosphere, ionosphere and upper atmosphere.
- All studies contributed to coupling from one discipline into another
- Studies and models were directly involved with understanding data from, or in planning future activities of, the following missions: YOKOH, SOHO, TRACE, SOLAR-B, SOLAR PROBE, STEREO, WIND, ACE, ULYSSES, POLAR, IMAGE, THEMIS, MMS, UARS, AE, DE, SME, DMSP, TIMED, SDO.

# CURRENT INVESTIGATIONS (2007 NRA)

- *Antiochos, Spiro K.*, Naval Research Laboratory  
**Magnetohydrodynamic Processes in the Solar Atmosphere**
- *Daughton, William*, Los Alamos National Laboratory  
**Towards Achieving Closure on key Problems in Collisionless Reconnection**
- *Fuller-Rowell, Timothy*, University of Colorado Boulder  
**Ionospheric Variability: Connections between Terrestrial and Space Weather**
- *Fisher, George*, University Of California Berkeley  
**Physical Connection between Solar Interior and Solar Atmosphere”**
- *Lotko, William*, Dartmouth College  
**Dynamics of Magnetosphere-Ionosphere Coupling**
- *Mikic, Zoran*, Predictive Science, Inc., San Diego  
**The Structure and Dynamics of the Solar Corona and Inner Heliosphere**
- *Matthaeus, William*, University of Delaware  
**Regulation of Energy Transport in Coronal and Interplanetary Systems: Connections between MHD and Kinetic Physics-Ionosphere**
- *Toffoletto, Frank*, William Marsh Rice University  
**Computational Studies of Magnetospheric Storm Dynamics**
- *Toomre, Juri*, U. Colorado Boulder  
**Solar Dynamo Probed with Simulations of Turbulent Convection, Magnetism and Shear.**

# SUN-TO-EARTH CONNECTION OF RESEARCH



Radial velocities near top of convection zone with downflows dark

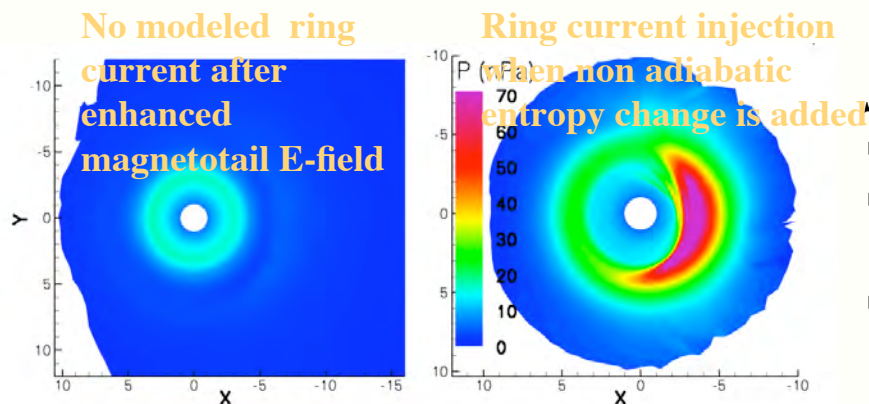
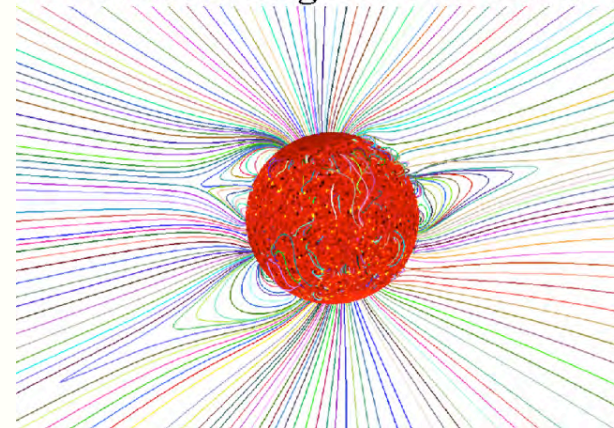
## SUN'S INTERIOR

- *Dynamics of Sun's differential rotation and tachocline boundary layer, dynamic processes in Sun's deep interior and magnetic flux transport to surface.*

## CORONA-SOLAR WIND

- *Eruptive phenomena and magnetic connection in corona, coronal heating and solar wind acceleration, dynamics of solar magnetic flux tubes.*
- *Solar wind structures and generation of energetic ions*
- *Turbulence in corona and solar wind*

## Predicted Magnetic Field Lines

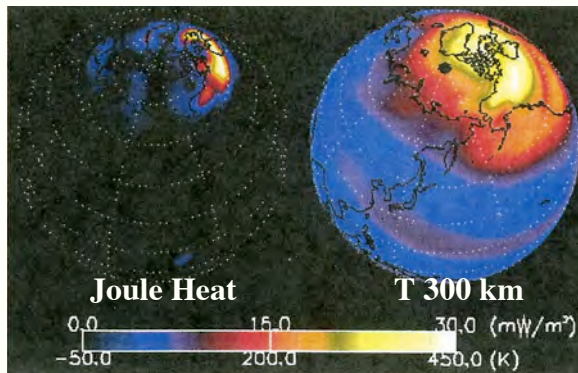


## SOLAR WIND-MAGNETOSPHERE

- *Solar wind interaction, reconnection*
- *Thin Current Sheets, substorms, micro- and macrophysics and their coupling to dynamics*
- *Inner magnetosphere, including inner plasmasheet, plasmasphere, ring current and radiation belts.*

## SUN-TO-EARTH CONNECTION OF RESEARCH (continued)

### High Latitude Energy Inputs and Traveling Disturbances



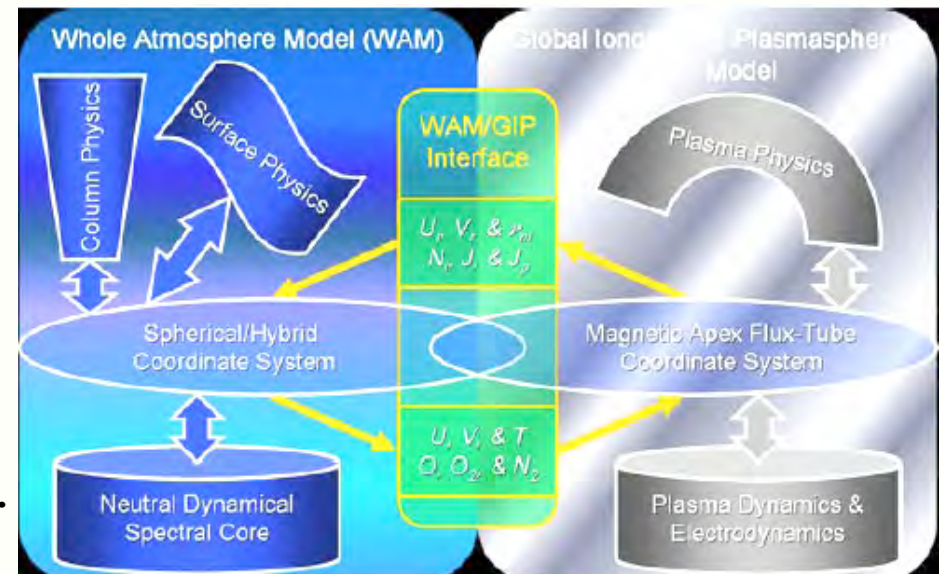
### MAGNETOSPHERE-IONOSPHERE

- *Magnetospheric Variability in ULF, magnetotail oscillations, magnetic pulsations, geomagnetic cavity and field line eigenmodes, auroral resonance/cavity dynamics.*
- *Response of coupled ionosphere-magnetosphere system to geomagnetic storms.*
- *Ionosphere-Polar Wind coupling and sources of magnetosphere plasma.*
- *Equatorial ionospheric disturbances due to high latitude magnetosphere disturbances.*
- *Dynamo feedbacks between magnetosphere and ionosphere.*
- *Thermosphere response to high latitude inputs*

### Integrated Dynamics through Earth's Atmosphere

### IONOSPHERE-ATMOSPHERE

- *Study of I-T system on different scales.*
- *Lower atmospheric sources of mesosphere/thermosphere disturbances,*
- *Upper atmosphere response to global change.*
- *Effects of tidal structures in middle atmosphere*
- *Source of low latitude electrodynamic variability.*



*Some* highlights from last 3-year HPTP  
research cycle follow